# Spectrometer-Matched Vertex Detector

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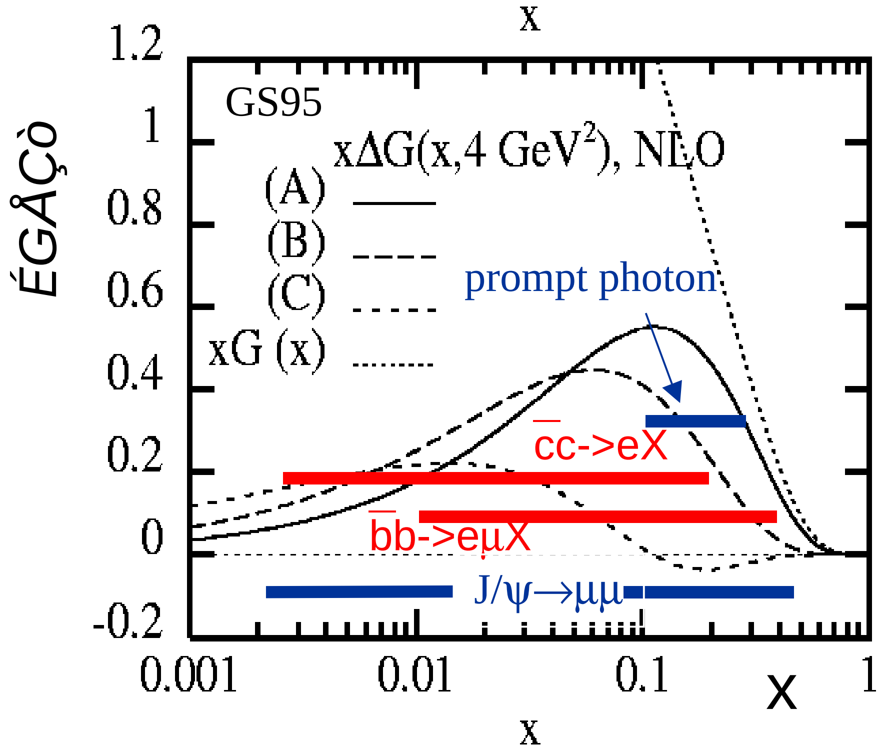
- Physics highlights
- Strawman plan of possible detector
- Proof-of-principle simulations
- Technology options

# Spin Structure Function of Proton

- Broad range of observables => low-x and large-x
- Vertex detector adds p+p => $c\bar{c}$ =>eX   p+p => $b\bar{b}$ =>eμX

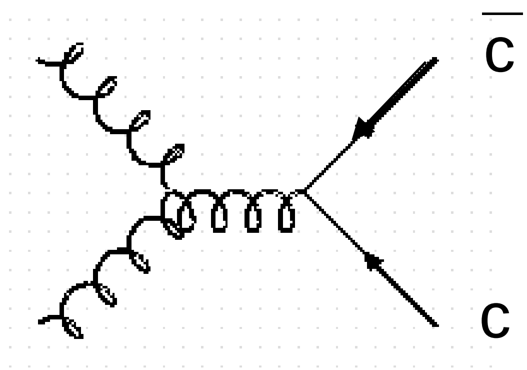



2 displaced vertices
e, μ b-tags

Explores production mechanism for variety of channels, global fit, how much spin does the glue carry

# pp => Charm, Bottom Production

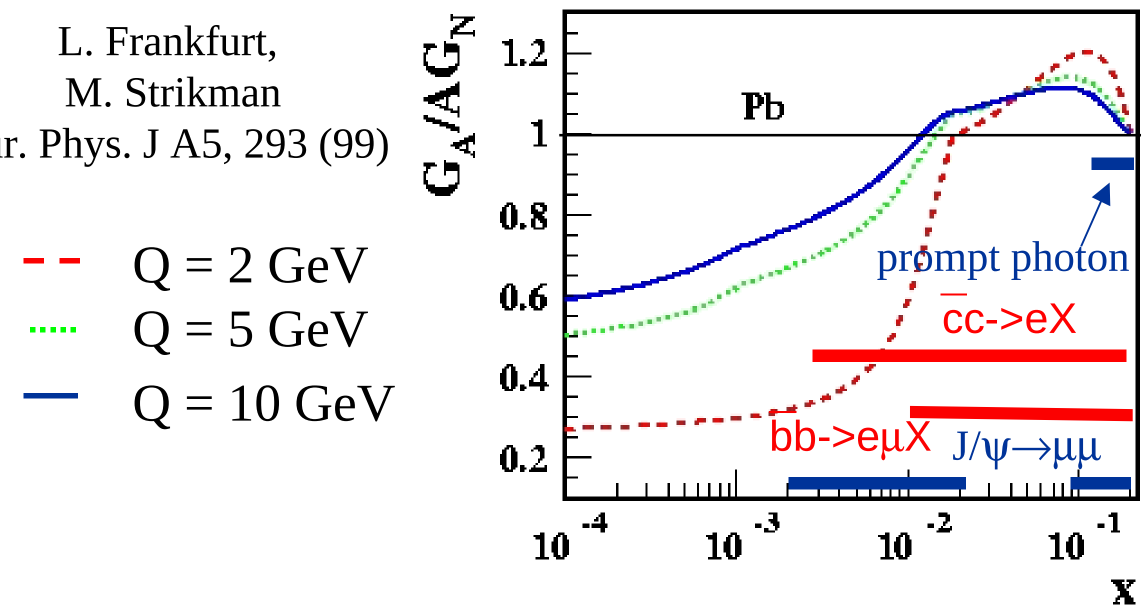
- Unique data on heavy-flavor production in this energy range
- Provides two baselines
  - empirical for comparison with AA data
  - theoretical
    - do we understand heavy-flavor production in QCD
    - beyond leading-order gluon fusion



# pA Charm, Bottom Production

- Reaction mechanism of heavy-flavor, e.g. initial state scattering
- Towards extracting gluon structure function nuclei, shadowing
  - consistency of several observables
- At very low-x, possibility of gluon saturation

L. Frankfurt,
M. Strikman
Eur. Phys. J A5, 293 (99)




Vertex detector adds
p+A => $\overline{c}c$ =>eX
p+A => $\overline{b}b$ =>eμX

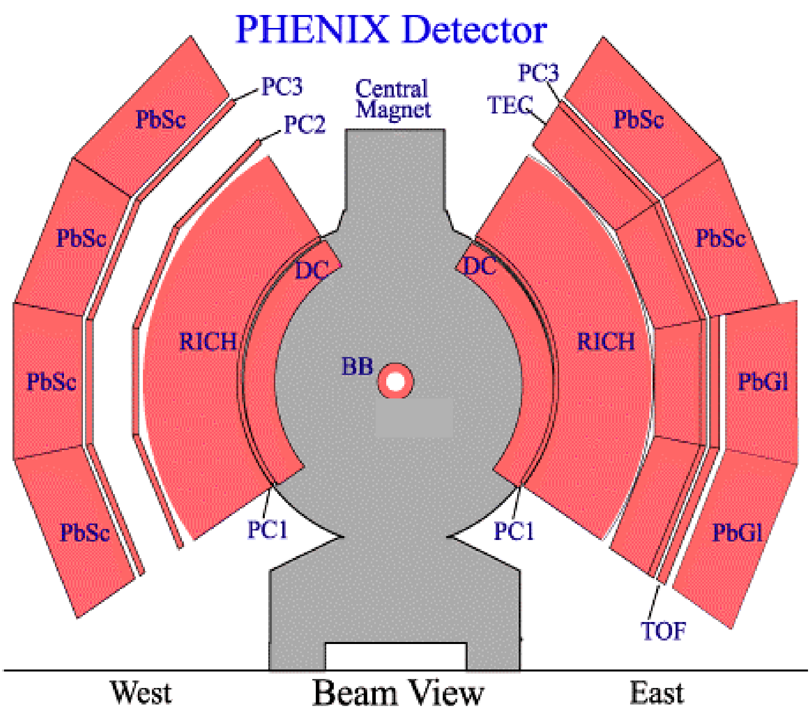
# AA Charm, Bottom Production

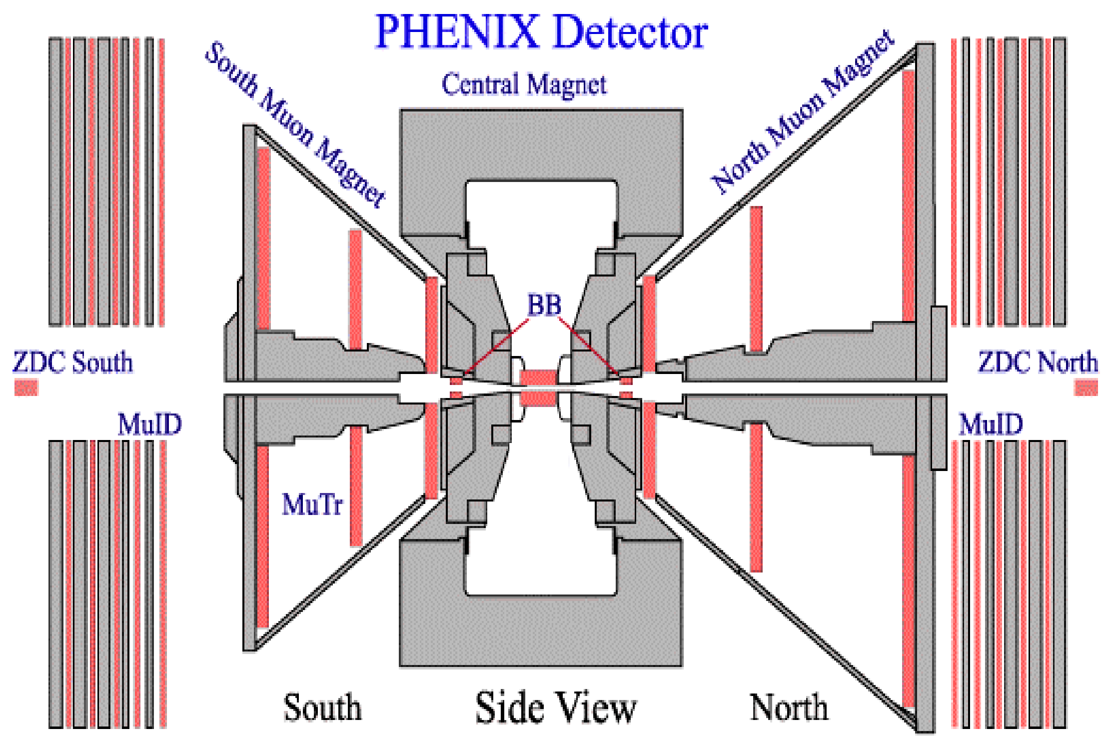
- Is charm enhanced by production in the earliest, densest stage of the reaction?
  - pre-equilibrium charm production
- How do high-pt heavy-quarks lose energy in the plasma?
  - does the mass of the parton affect the medium-induced gluon radiation?

- Measure both the pt spectra and yield of open charm, bottom
  - pp, pA and AA
    - AA centrality and species dependence

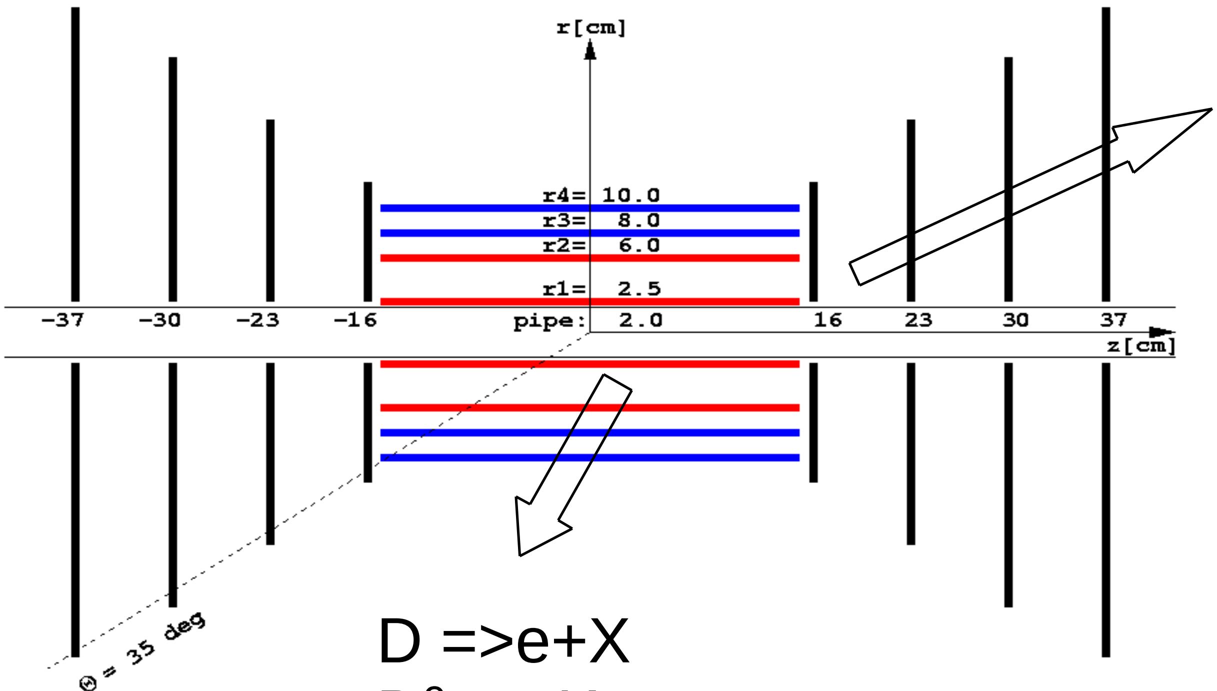
# Spectrometer-Matched Vertex Detector

- Match tracks, displaced vertices to PHENIX spectrometer arms
  - electron PID, muon tracking/PID



# Strawman Detector Principles (numbers next)




D =>$\mu$+X

D =>e+X

$D^0$ => $K^- \pi^+$

Performance requires matching tracklets to tracks in muon-arms

$\Rightarrow$p-measurement

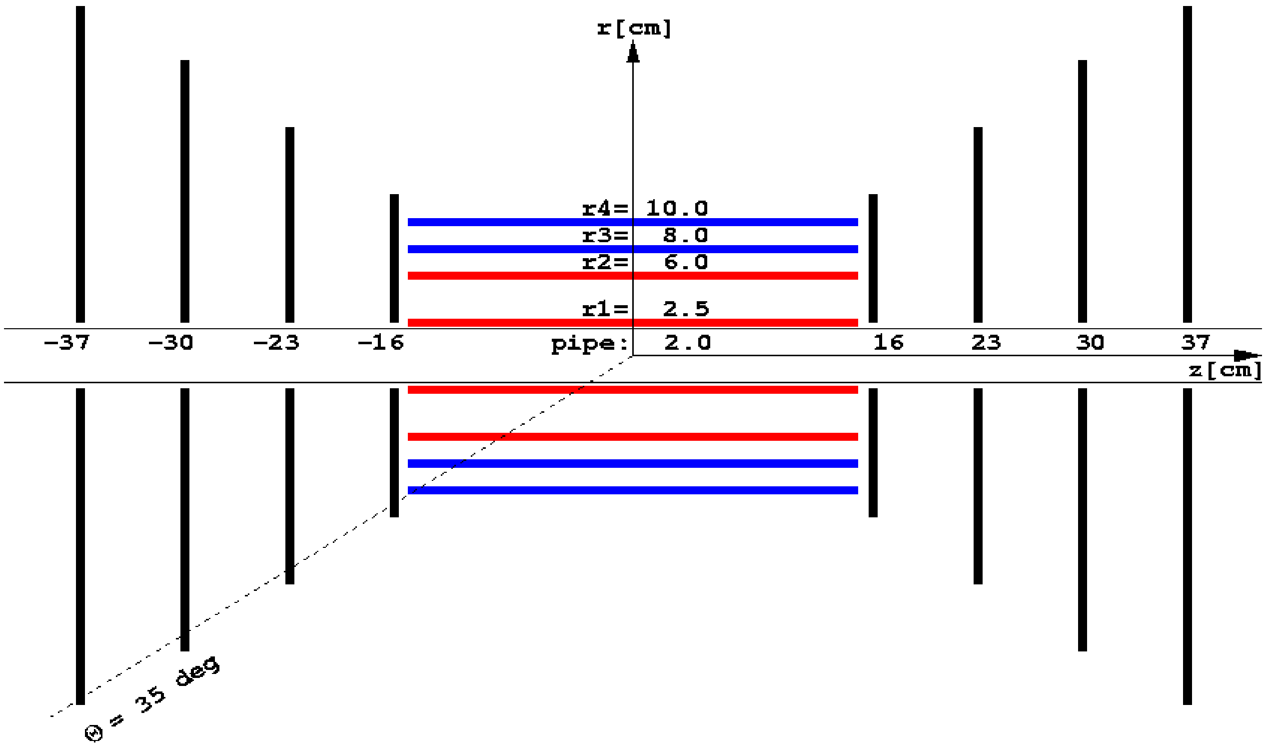
$\Rightarrow$displaced vertex

Performance requires accurate projection to collision vertex

=> close, thin detector

# Strawman Detector

Each Si layer, 1% radiation length {detector, cooling, support}




GEANT

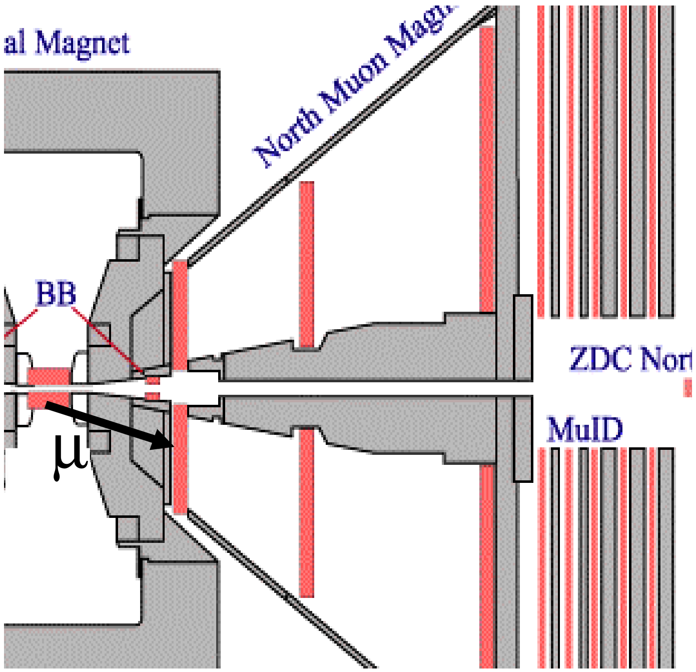
*** pixel barrels**
*** strip barrels**
*** pixel disks**

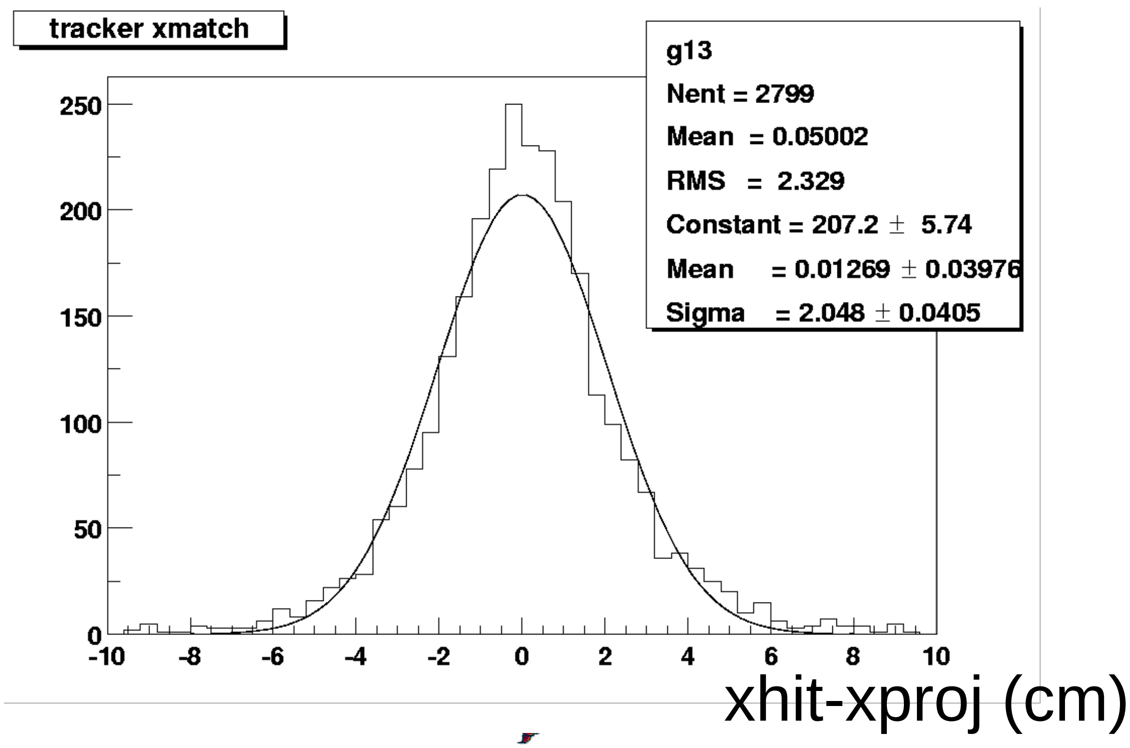
endcap, pixels
4 circular disks
z=16, 23, 30, 37cm
$1.2 < |\eta| < 2.4$

- Barrel r = 2.5, 6, 8, 10 cm, $-1.2 < \eta < 1.2$
  - inner two layers, Si pixels
  - outer two layers, Si strips

# Matching to Muon Arms

- Match tracklets in Si to muon spectrometer
  - cut on same charge
  - momentum similar to 50% before/after muon shielding
  - match hit within 3$\sigma$ on first tracking layer

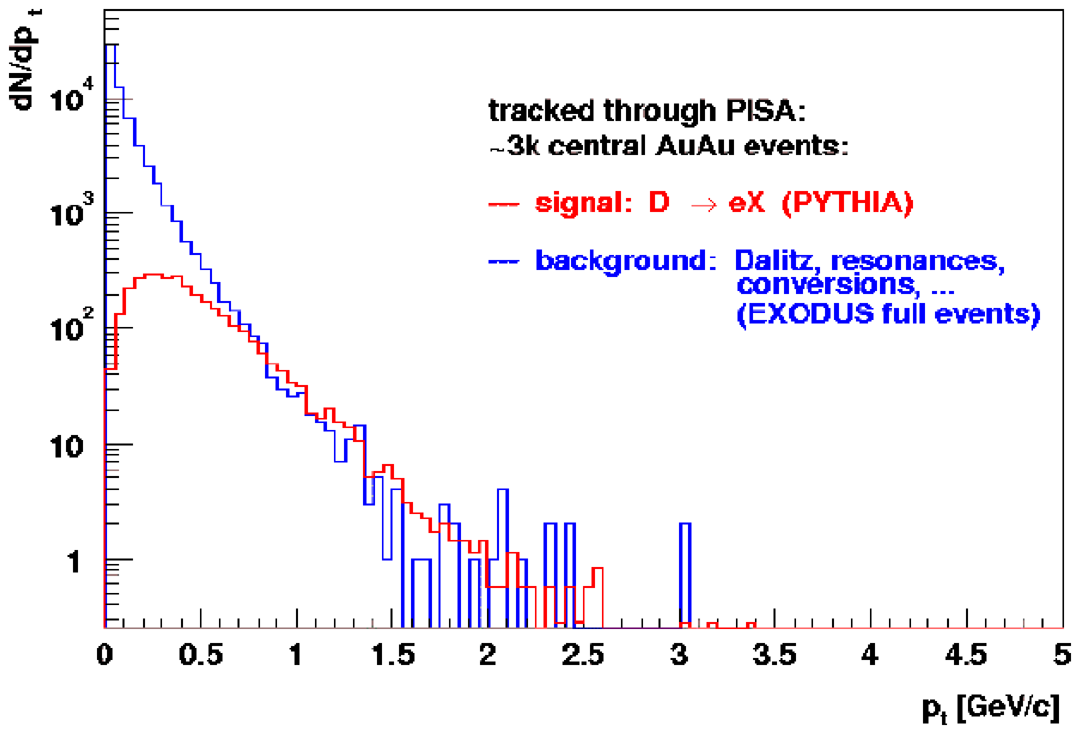


# Signal/Background Muons from Charm

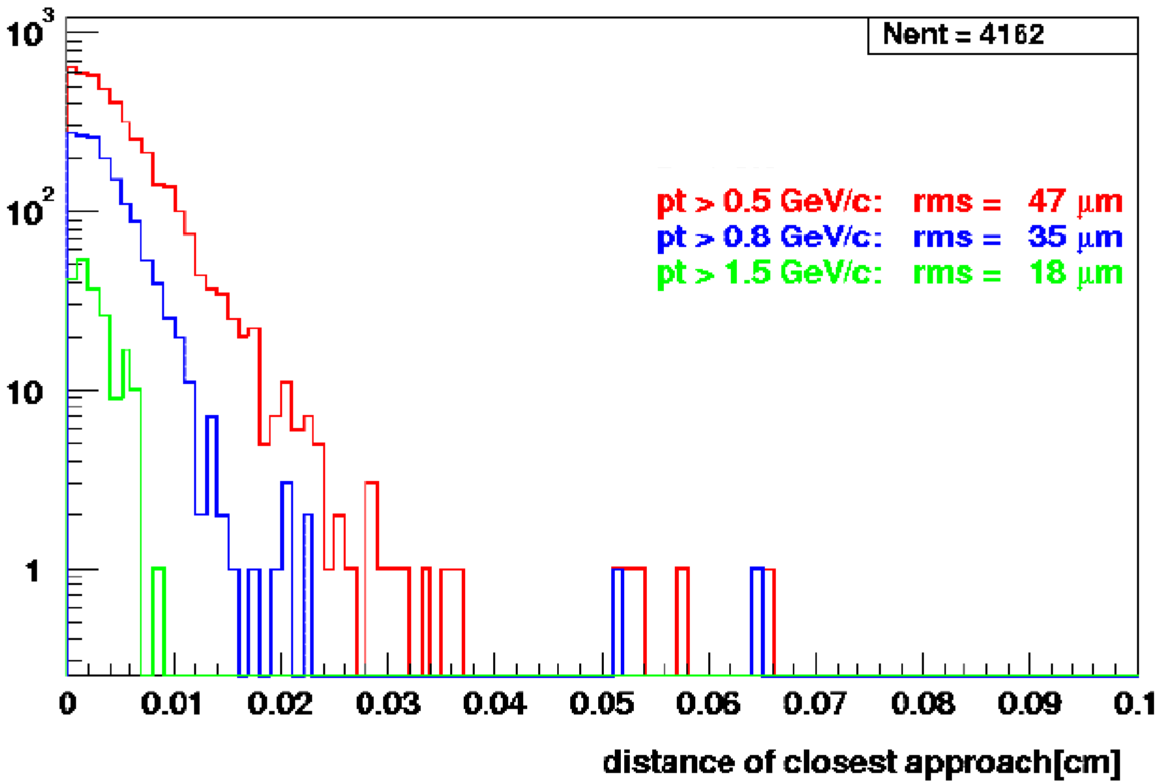
- p+p simulations (in progress)
  - tracklets matched to muon spectrometer
  - DCA resolution to collision vertex ~ 100μm
  - identify displaced decays, candidate μ from D, B
  - D =>μ+X
    - » confirm by having displaced track (X) in coincidence
  - upper cut on decay removes long-lived pion decays
  - (μ from D)/(μ from π)
    - » S/B > 1 for pt > 0.5 GeV/c
  - will enable measurement of spectra of open charm

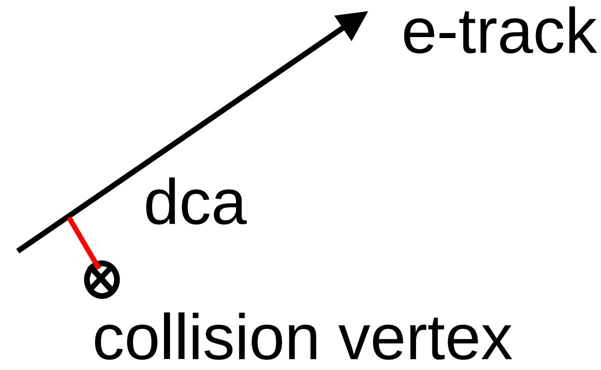
# Central Arm: Electrons from D decay (Au+Au Simulations)




- Without cuts on displaced vertex
  - S/B ~ 1 for high-pt
  - S/B ~ 0.1 pt=0.5 GeV/c

# Distance of Closest Approach



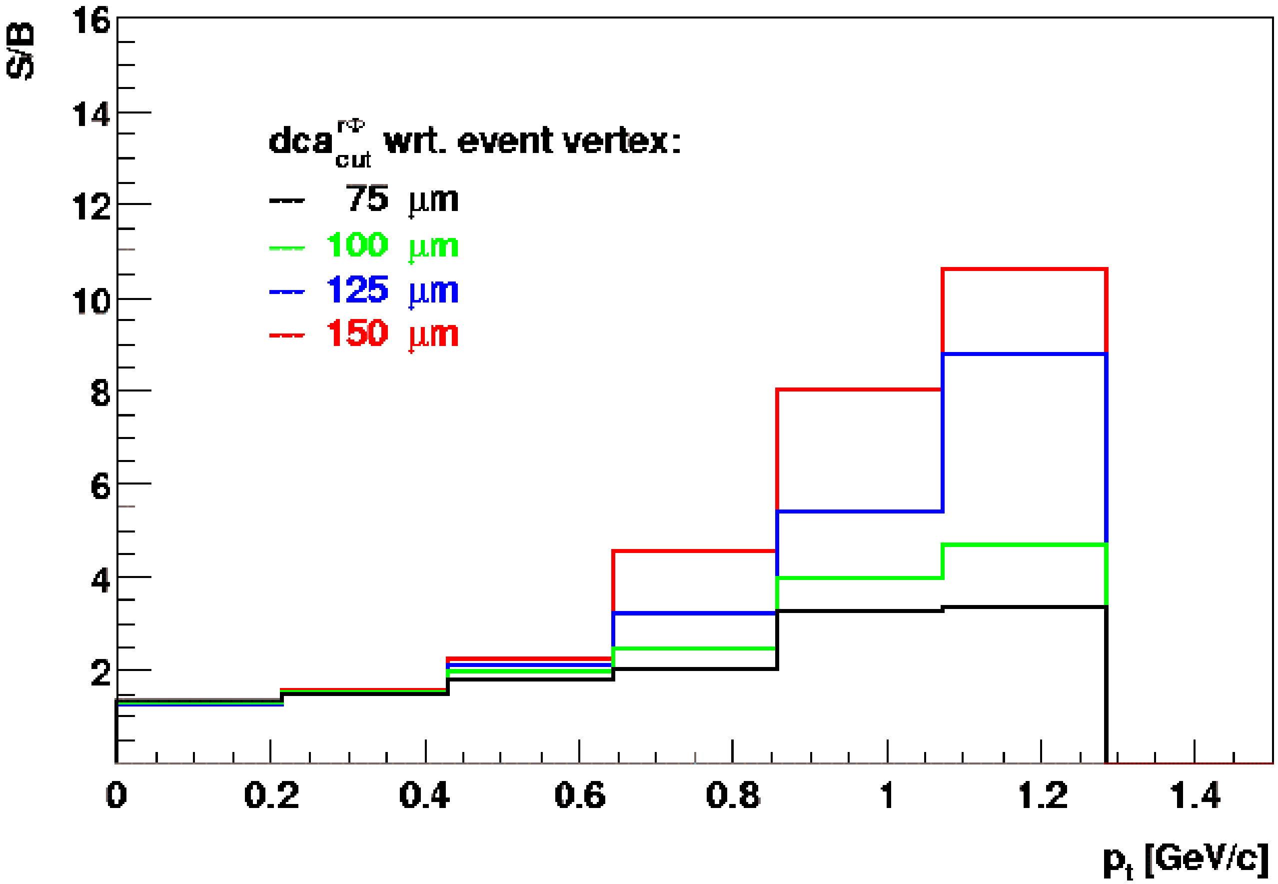




50µm x 425µm pixels, full multiple scattering

dca resolution (electrons) < 50 µm

less than cτ, $D^0$: 125µm $D^{\pm}$: 317 µm

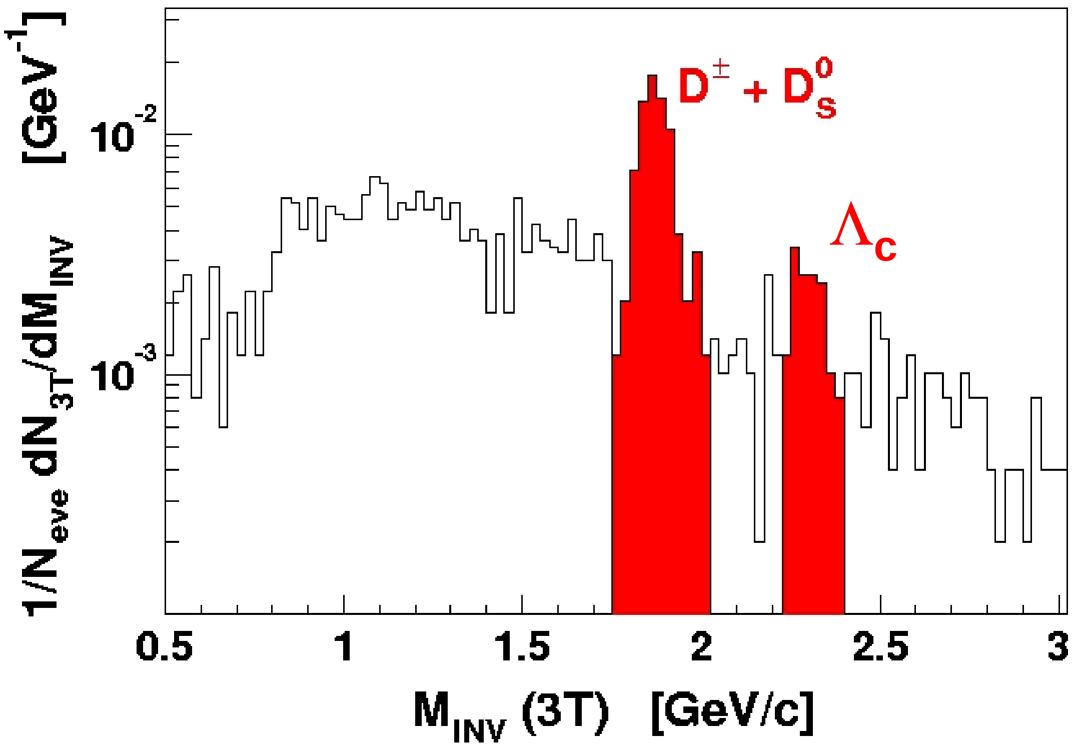
# Signal/Background With DCA Cut




- S/B from 2 to 10 => sample largely e from D-decay
  - large momentum range => spectra and yields of D

# Hadronic Decays of D

- Construct invariant mass => extract counts => spectra
  - multiple scattering, slow hadrons, makes this very tough




$D^+ \Rightarrow K^- \pi^+ \pi^+$ (BR 9%)
full multiple-scattering
three displaced tracks,
parent points to collision

- Provides 2nd measure of D spectra, consistency with D=>e+X

# Other Physics

- Large solid angle => “jet” axis reconstruction in pp, pA
  - photon+jet
- Rejection of Dalitz and conversion e+e- pairs
  - cut on small $e^+e^-$ opening angle, small invariant mass
  - improve S/B near low-mass vector meson, $\rho$, $\phi$
- Strange baryons, $\Lambda$, $\Xi$, $\Omega$
  - confirm by-then-existing STAR results
- Better angle measurement for $\mu$+$\mu$- pairs
  - improved mass resolution for all vector mesons
    - » J/$\psi$, $\psi$’
- Reduction of $\pi$=>$\mu$ background
  - increase S/B for Upsilon, Upsilon spectroscopy
  - Displaced J/$\psi$ => B-yields in AA, rates ?

# Technology Options

- Si Pixel: hybrid
  - RIKEN and PHENIX collaborators joined NA60/ALICE 1st round of production
  - gain experience, explore matching readout to PHENIX
- Si Pixel: monolithic
  - Iowa State effort with Electrical Engineering Dept
    - modify commercial APS designs
    - readout speed?, thick epitaxial layer?
- Si “Pads”: BNL (Zheng Li) 100μm*1mm, wire bonded
- Strips: no problems foreseen

# Vital Statistics

- Total silicon surface area = 1.4 $m^2$
- Barrel pixels 5M
- Barrel strips 50K
- Endcap pixels ~ 12M
- Requires zero suppression
- Two estimates of data volume per central event
  - hit channels (real+background) => 80K channels
  - 97% zero suppression => 500K channels
- No discussion yet on trigger possibilities

# Strawman Schedule

- Considering a staged schedule
  - support/cooling for full barrel/endcap
  - instrument outer two barrel layers with Si-strip (2004-05?)
  - instrument inner layers/endcaps with pixels (2005-06?)
- Enables spin, pp, pA program early
- Parallel tasks implies challenges for manpower, $$
  - R&D on Si pixel options
  - implementing Si strips

# R&D effort

- LANL LDRD Funds, 250K / year next 3 years,
  - detector design, optimization
  - evolve to pixel studies
- RIKEN /Suny SB
  - NA60/ALICE hybrid pixel participation (2 people 2002)
  - adapt for PHENIX needs
  - Si strip/pads with BNL
- Iowa State
  - monolithic APS design/fabrication
- BNL
  - sparse readout

# Summary

- Physics case for spectrometer-matched vertex tracker
  - gluon spin structure function from low-x to large-x
  - gluon shadowing in nuclei
  - charm enhancement in early-stage of heavy-ion collision
  - energy-loss of high-pt heavy quarks
- Measure spectra broad pt range, yield of open charm, bottom
  - pp, pA, and AA collisions
- Strawman detector simulations
  - displaced muons (res. 100 $\mu$) match to muon-spectrometer
  - electron DCA resolution (50 $\mu$) < $c\tau$ for D decay
  - D => $K\pi\pi$ promising
- Explore technology options, simulate performance